Quick Introduction: ISO/IEC-test chart files which show basic problems of colour reproduction and produce equal output for corresponding colours defined in CIELAB related device spaces

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Abstract

The device output of ISO/IEC-test chart files which include colours defined in the CIELAB colour space and the corresponding device dependent colour spaces shows a lot of problems. The correponding colours produce **very different** output or **no output difference** on monitors and printers. Sometimes for the present **standard software** the monitor output is **very** different and there are **no** output differences on printers or vice versa. If a **PostScript MTL code** (Measurement, Transfer and Linearization) is added to the code of an ISO/IEC-test chart (the **NP** file) then the output of the new **FP** file produces the same output as expected by users and CIE colorimetry if CIELAB colours and related device dependent colours are used for input. For this intended output property the definition of the Colour Workßow (CW) and the Output Linearization (OL) is included in all ISO/IEC-test charts of the **FP** form.

‹ Remark: The output of this paper produces large color differences (often 20 CIELAB) for the **NP** files on most printers and monitors. The large colour differences for corresponding colours of different colour spaces are **not** intended by users and CIE colorimetry. The output of the **FP** files produces **no** colour differences as intended.

1.0 Variety of colour spaces with corresponding input PS operators

There is a variety of colour spaces which can be used for input and output. Any user has to spend a lot of time to learn about the different spaces and to train the relationship of the different spaces which depends on application.

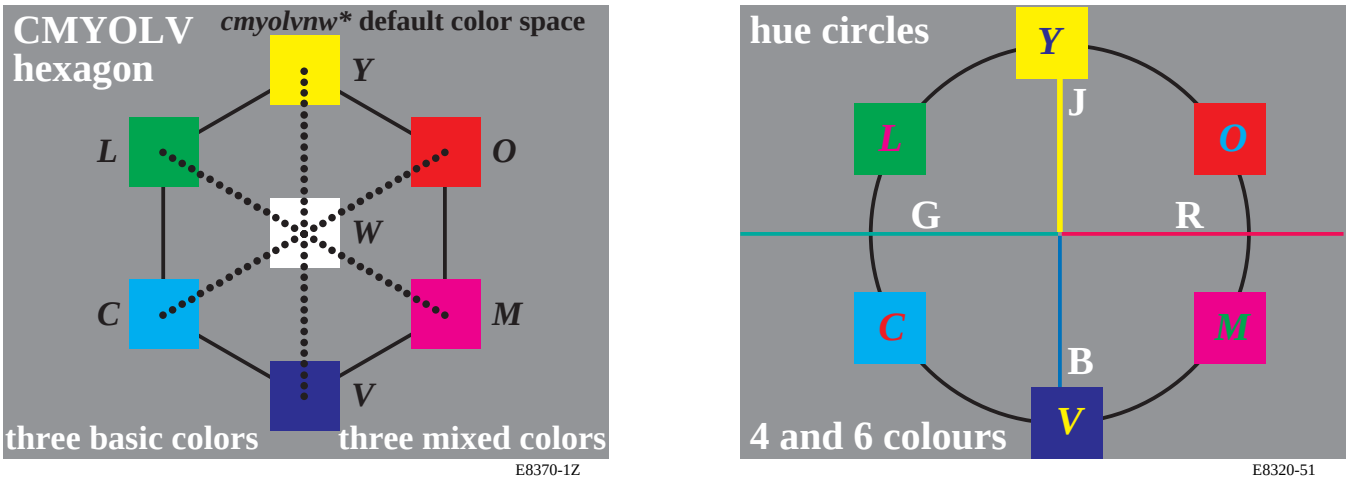

Figure 1: Six reproduction colours CMYOLV and four unique hue colours RJGB according to ISO/IEC 15775 defined in CIELAB colour space

Fig. 1 shows the six chromatic colours **CMYOLV** and Black **N** (=noir) and White **W** of standard offset printing (left). The four unique hue colours **RJGB** are different from the six reproduction colours. Standard non ßuorescent offset paper was used to produce the **analog ISO/IEC-test charts which are equally spaced in CIELAB coordinates**. There are productions of DIN and JBMA (Japan Business Machines Association) in reßective and transparent mode. The German DIN production has been measured with the 45/0 measuring geometry for standard illuminant D65 and the CIE 1931 standard observer at BAM *(Laboratory S.13)*. The mean colour difference of CMYOLV compared to the standard data is 2.5 CIELAB, see the standard DIN 33866-X [1] and the International Standard ISO/IEC 15775 [2].

Remarks: According to the International Standard ISO/IEC 15775 the letters ***j*** (=jeanne=yellow), ***r*** (red), ***g*** (green), and ***b*** (blue) are reserved for the unique hues and the letters ***olv**** (orange red, leaf green, violet blue) are used with a star to indicate the linear relationship to CIELAB. The ***olv**** coordinates are used for the reßective

colours and are used in a similar way as the coordinates ***rgb*** of the luminous television colours. The ***cmy**** coordinates are alternate coordinates compared to ***olv**** (see Fig. 1 and Table 1 and 2).

All the 16 step colour series between white and the six chromatic colours CMYOLV (see Fig. 1) and black are equally spaced in the CIELAB colour space. Laser printers produce the six chromatic colours by between 3 and 6 (e. g. a printer of the company Oc∂) colorants. The result is very similar compared to the six colours CMYOLV of the present analog ISO/IEC-test charts which has been produced by standard offset printing.

The halftone screening of laser printers (or of offset printing) produce colours which are approximately on a line e. g. between White W and Cyan C in the CIELAB space. This is one basic assumption of the model colour space. In practice the 16 colours between White and Cyan may slightly deviate by less then 3 CIELAB from the line in CIELAB space. This is much less compared to the spacing differences along the line W ‹ C of 20 CIELAB which printers often produce. For the office applications it was therefore the basic task to reduce the spacing differences along the 16 step series C ‹ W below 3 CIELAB. Then all Landolt-rings in the ISO/IEC-test chart output are recognized. A naive user requires that along the line W ‹ C only the cyan coordinate of *cmy** changes between 0 and 1 in 15 digital steps of 1/15. The other coordinates are cero. In the alternate coordinate system *olv** the Orange red coordinate is cero and the other two change by equal amounts from cero to 1 in steps of 1/15 (see Table 2).

There were **two task** to solve: **Linearization** (equal CIELAB spacing) of the seven series W to CMYOLVN and **calculation methods** of the coordinates *cmy** and *olv** from the CIELAB data of the standard (and the analog samples) and vice versa. Both tasks have been solved by a PostScript MTL code (MTL=Measurement, Transfer and Linearization). If a device is linearized along the lines in CIELAB space then there are linear relationships between the coordinates *cmy*, olv*,* and *LAB** of the CIELAB colour space. The linear relations (and as a result a linear additive metric in CIELAB space in each of the six sectors of Fig. 1) are used in the PS MTL code. Either the ***olv*, cmy*, or LAB**** data can be used in an **ISO/IEC-test chart** file to get the **same** output on a printer or monitor. There is a lot of additional material on the web site

http://www.ps.bam.de

Colour series Black ‹ White (N ‹ W) of ISO/IEC-test chart 3 (5 steps)						
Six **colour spaces** and **coordinates**	**CMYN (CMYK) (000n*)**	**GREY (w*)**	**CMYN (CMYK) (cmy0*)**	**OLV (RGB) (olv*)**	**CIELAB relative (lab*)**	**CIELAB absolute (LAB*)**
six input **PS operators**	**000n* setcmykcolor**	**w* setgray**	**nnn0* setcmykcolor**	**www* setrgbcolor**	**lab* setcolor**	**LAB* setcolor** see ISO/IEC 15775, Table H.6
data for black **N**	0.00 0.00 0.00 1.00	0.00	1.00 1.00 1.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00	18.01 +0.50 -0.46
data for dark grey **D**	0.00 0.00 0.00 0.75	0.25	0.75 0.75 0.75 0.00	0.25 0.25 0.25	0.25 0.00 0.00	37.36 +0.13 +0.84
data for mean grey **Z**	0.00 0.00 0.00 0.50	0.50	0.50 0.50 0.50 0.00	0.50 0.50 0.50	0.50 0.00 0.00	56.71 -0.24 +2.15
data for light grey **H**	0.00 0.00 0.00 0.25	0.75	0.25 0.25 0.25 0.00	0.75 0.75 0.75	0.75 0.00 0.00	76.06 -0.61 +3.45
data for white **W**	0.00 0.00 0.00 0.00	1.00	0.00 0.00 0.00 0.00	1.00 1.00 1.00	1.00 0.00 0.00	95.41 -0.98 +4.76

Table 1: Colour data of the 5 step colour series N ‹ W for six input PS operators in six colour spaces

Table 1 include six input *PostScript* (PS) operators which define the same achromatic colours black, three greys and white. Between one and four input data are necessary for the complete definition of the achromatic colours depending on the colour space.

Colour series Cyan blue ‹ White (C ‹ W) of ISO/IEC-test chart 2 (5 steps)			
Three colour spaces and **coordinates**	**CMYN (CMYK) (cmy0*)**	**OLV (RGB) (olv*)**	**CIELAB absolute (LAB*)**
Three input **PS operators**	**cmy0* setcmykcolor**	**olv* setrgbcolor**	**LAB* setcolor** see ISO/IEC 15775, Table H.2
1.00 **C** + 0.00 **W** (Cyan blue **C**)	1.00 0.00 0.00 0.00	0.00 1.00 1.00	58.62 -30.62 -42.74
0.75 **C** + 0.25 **W**	0.75 0.00 0.00 0.00	0.25 1.00 1.00	67.82 -23.21 -30.86
0.50 **C** + 0.50 **W**	0.50 0.00 0.00 0.00	0.50 1.00 1.00	77.02 -15.80 -18.98
0.25 **C** + 0.75 **W**	0.25 0.00 0.00 0.00	0.75 1.00 1.00	86.21 -08.39 -07.11
0.00 **C** + 1.00 **W** (White **W**)	0.00 0.00 0.00 0.00	1.00 1.00 1.00	95.41 -00.98 +04.76

Table 2: Colour data of 5 step colour series C ‹ W for three input PS operators in three colour spaces

Table 2 includes three input *PostScript* (PS) operators which define the same chromatic colour series between Cyan blue and White. There are ISO/IEC-test chart files which use the different PS operators of Table 1 and 2.

2.0 Figures of ISO/IEC-test chart files (NP and FP form) in different colour spaces

Main and important software products on *Windows* and *Mac* fail to produce the same colours as required by any user and CIE colorimetry for many of the following files. The first four different PS operators of Table 1 are used to reproduce a 16 step grey scale by the **NP** file.

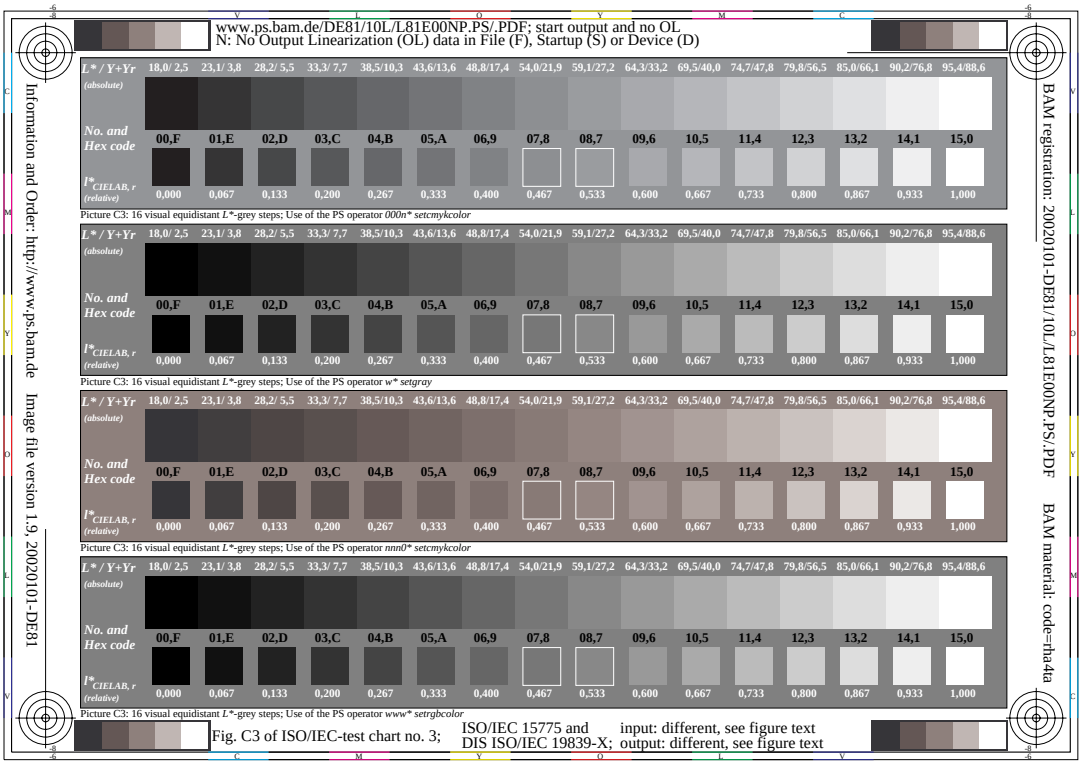

Figure 2: Fig. C3 of ISO/IEC-test chart 3; the corresponding colours are defined by four input PS operators without any transfer; original NP file see web (click to go always on the left (blue) part of the web address)

http://www.ps.bam.de/DE81/10L/L81E00**NP**.PDF

Fig. 2 is called the start output which is produced always by an **NP** file. The monitor output shows at least 2 different grey scales by the software *Adobe Reader* but *Mac Preview* shows **no** difference for the four scales. The output on a few printers shows **no** difference but most printers show up to **four different** scales. Any **user requires the same output** which must be independent of the input PS operator used. The required **identical output** of the four identical grey scales is produced by the **FP** file which differs from the **NP** file by the additional **PostScript MTL code**.

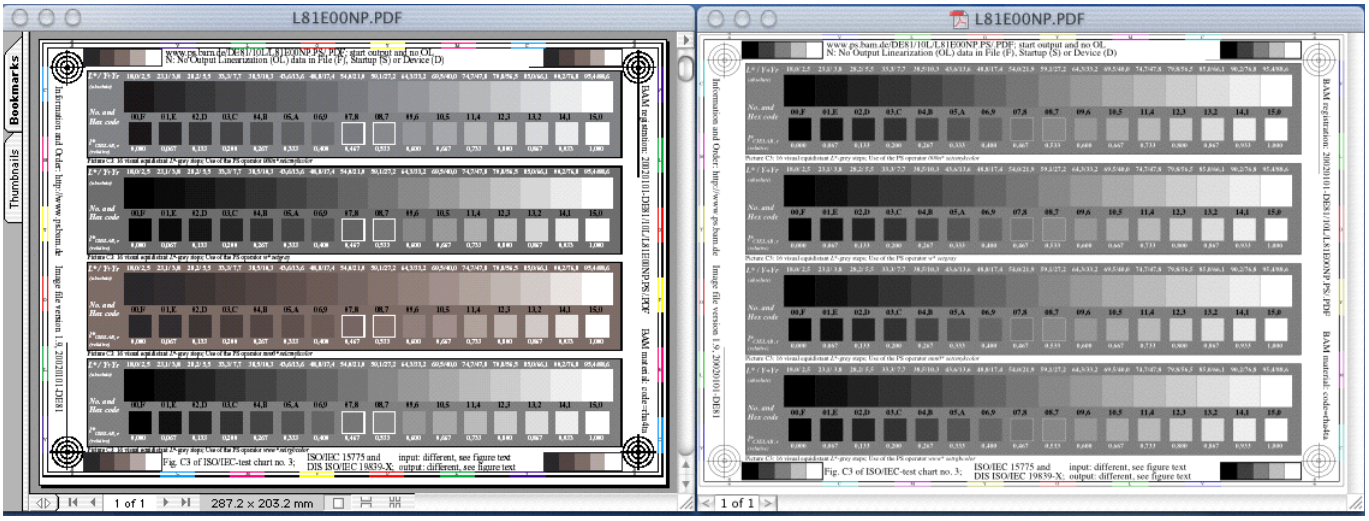

Figure 3: Fig. C3 of ISO/IEC-test chart 3; the corresponding colours are defined by four input PS operators without any transfer; see for the original screen photo:

http://www.ps.bam.de/DE81/10L/L81RP0**NP**.tiff

Fig. 3 shows a screen photo on the computer operating system *Mac OS X 10* which shows the same **NP** file (shown already in Fig. 2) by both the software *Adobe Reader (left)* and by the software *Mac Preview (right)*. Is is obvious that

Mac Preview agrees with the user requirement and CIE colorimetry.

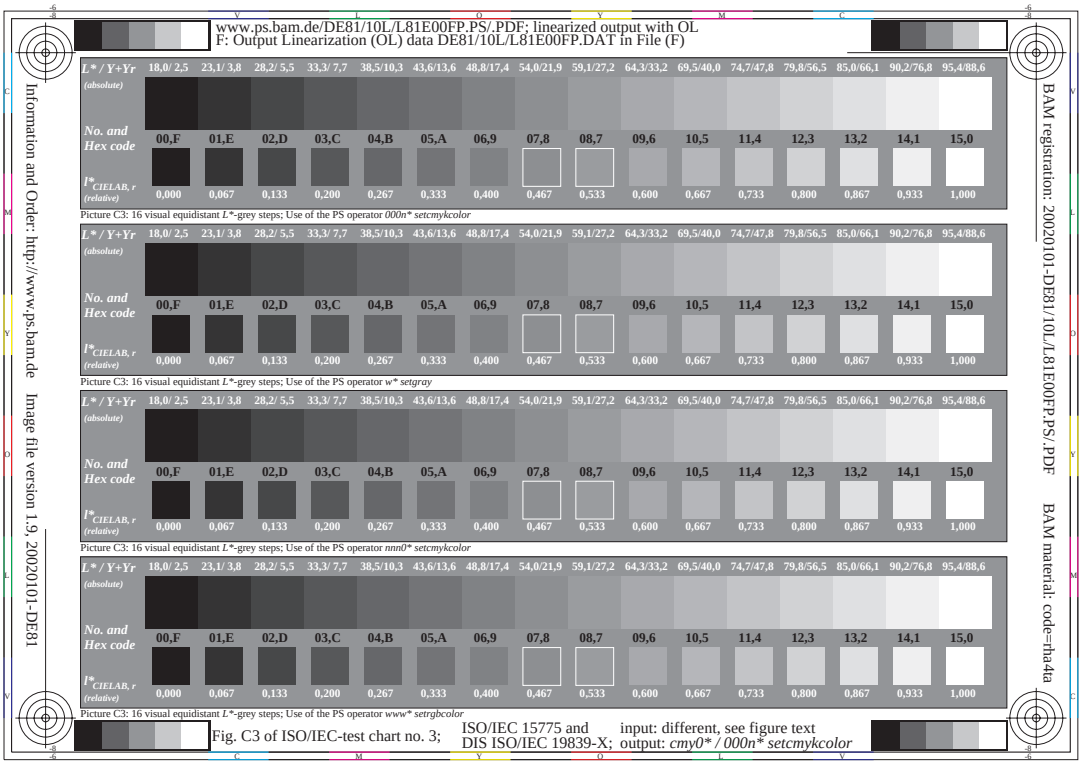

Figure 4: Fig. C3 of ISO/IEC-test chart 3; Transfer from four input to one output PS operator, see for the original FP file

http://www.ps.bam.de/DE81/10L/L81E00**FP**.PDF

Fig. 4 shows the **PF** file output. The four input PS operators are transferred to one output PS operator. For a mean grey instead of the CIELAB lightness *L**=57 often the lightness *L**=37 or 77 is reproduced (see Table 1, last column, colour difference 20 CIELAB). But the tolerance range is only 57+/-3 for office devices according to ISO/IEC 15775.

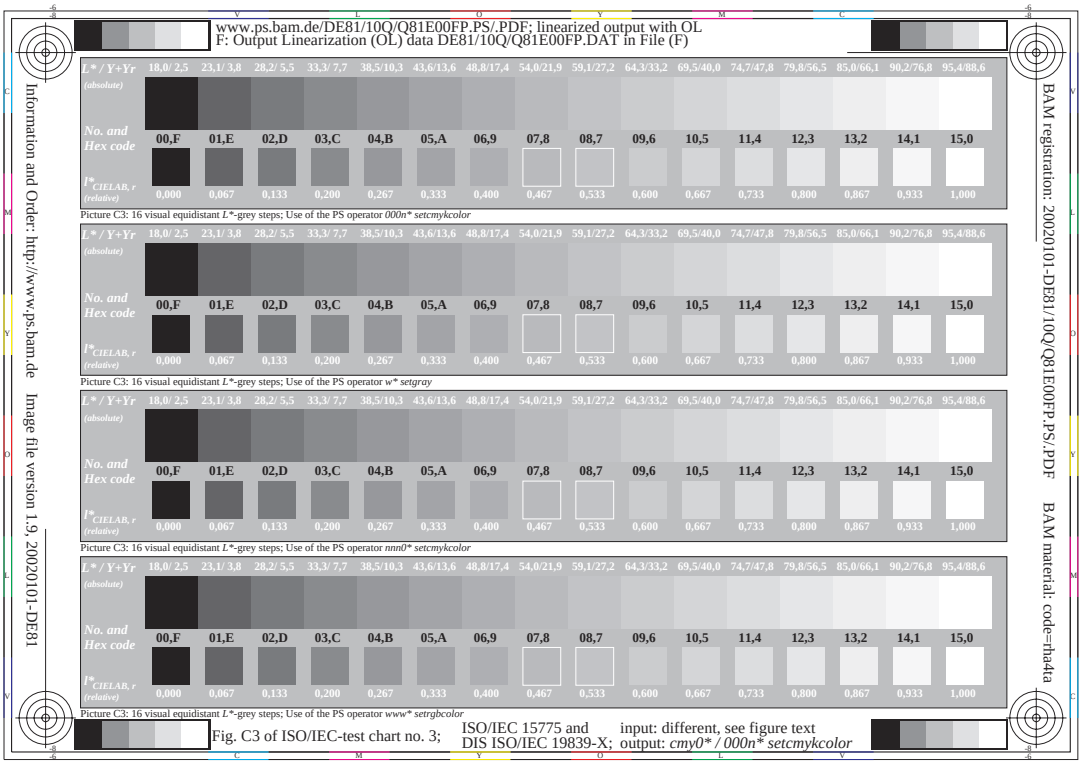

Figure 5: Fig. C3 of ISO/IEC-test chart 3; Transfer to *lighter* colours compared to the standard colours (Fig.2) from four input to one output PS operator, see for the original FP file

http://www.ps.bam.de/DE81/10Q/Q81E00**FP**.PDF

Fig. 5 shows a lighter **FP** file output which may look on some devices more equally spaced. The required 16 step **standard output** which is equally spaced in CIELAB is produced if a user measures the *LAB** data of the **NP** file output and if he replaces the L=Linear default output *LAB** data by the *LAB** measurement data in the MTL code of the **FP** file. The PostScript or PDF interpreter prints the corrected **FP** file and uses the *LAB** data to produce the required 16 step output which is equally spaced in CIELAB for any device

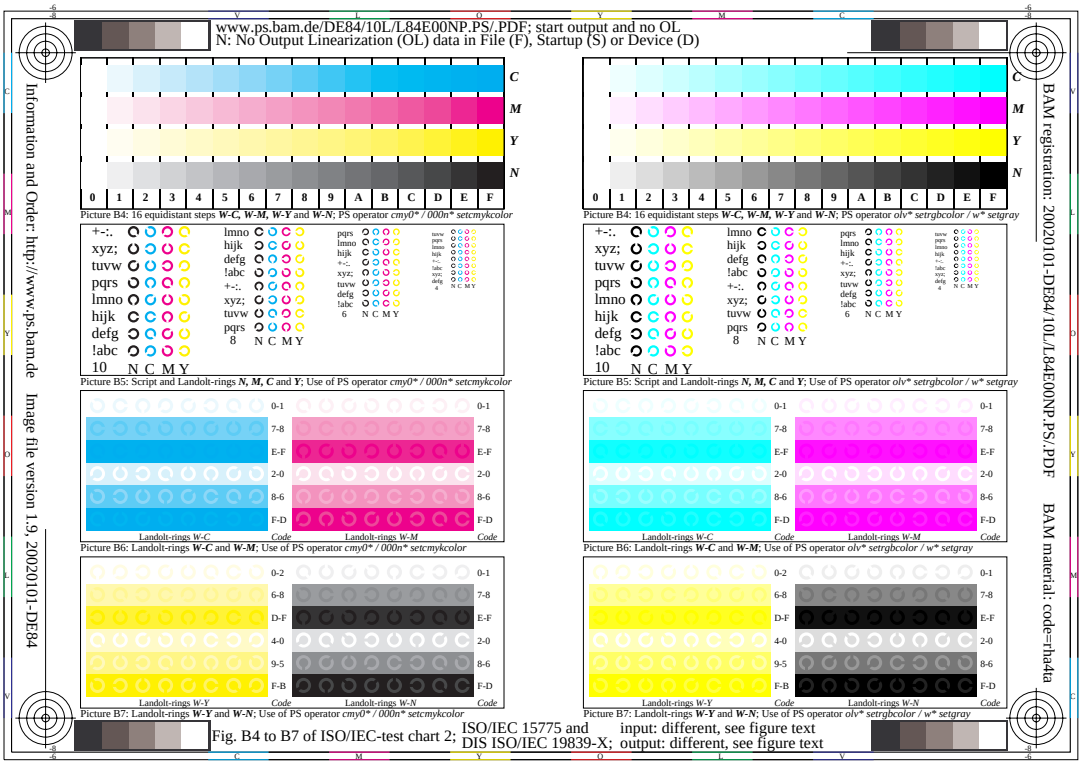

Figure 6: Fig. B4 to B7 of ISO/IEC-test chart 2; corresponding colours are defined by two input PS operators without transfer; there are output differences; see for the original NP file

http://www.ps.bam.de/DE84/10L/L84E00**NP**.PDF

Fig. 7 shows again (compare Fig. 2) for two different input PS operators (see left and right in the figure) a **different** output by the software *Adobe Reader* and **equal** output by the software *Mac Preview* as required by naive users.

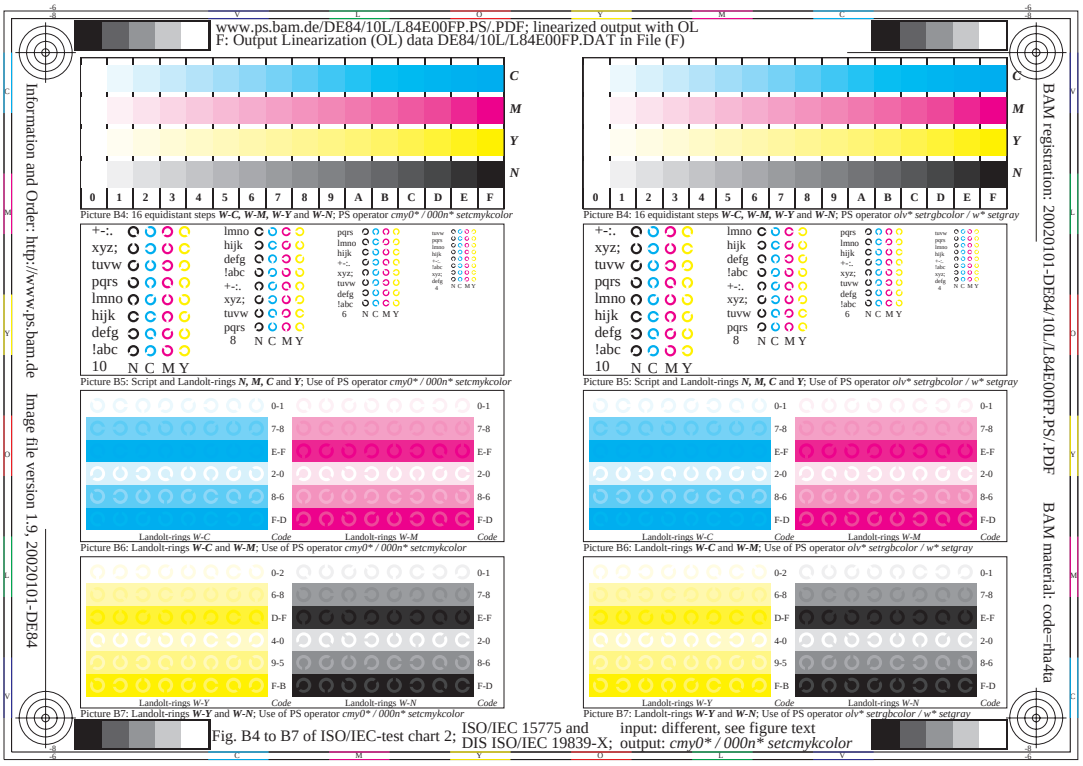

Figure 7: Fig. B4 to B7 of ISO/IEC-test chart 2; corresponding colours are defined by two input PS operators which are transferred to one output PS operator *cmy0* / 000n* setcmykcolor*; see for the original FP file
http://www.ps.bam.de/DE84/10L/L84E00**FP**.PDF

Fig. 7 shows again an **FP** file output (compare Fig. 3). The **two** input PS operators are transferred to **one** output PS operator. The MTL code in the **FP** file again produces the **same** output (compare Fig. 3) for the different input PS operators used on one page for any software used *(Adobe Reader or Mac Preview).*

All the different input PS operators of Table 1 and 2 are used in the improved ISO/IEC-test charts (**NP** files) no. 2 to 4 and allow to test the colour reproduction of the different devices and the different software. The ISO/IEC-test charts (**FP** files) which include the PS MTL code (Measurement, Transfer and Linearization) produce the same output for any of the six input operators of Table 1 used. If with ISO/IEC-test charts the Output Linearization (OL) is applied then the output is within the CIELAB tolerance range of 3 CIELAB which is intended for colour office devices according to ISO/IEC 15775. The Colour Workßow (CW) which is the transfer from the input to the output PS operators and the Output Linearization (OL) is done by the PS MTL code (Measurement, Transfer and Linearization) which is included in the ISO/IEC-test charts (**FP** files).

Remark: The PS MTL code determines the output in the same direction if stored at one of the following places

1. the file (Remark: If the MTL code is added to the ISO/IEC-test chart 4 (NP-file) then this file is called the FP file)
2. the PostScript Printer Memory
3. the PPD file (PostScript Printer Description)
4. Adobe Distiller Startup Directory
5. Display PostScript Memory

Remark: For screen photos and the application of no. 4 there are examples at

http://www.ps.bam.de/DE81/DE81D.HTM

3.0 ISO/IEC-test chart files (NP and FP form) in different colour spaces

The more important and complete **NP** and **FP** files of the ISO/IEC-test charts are shown in the following.

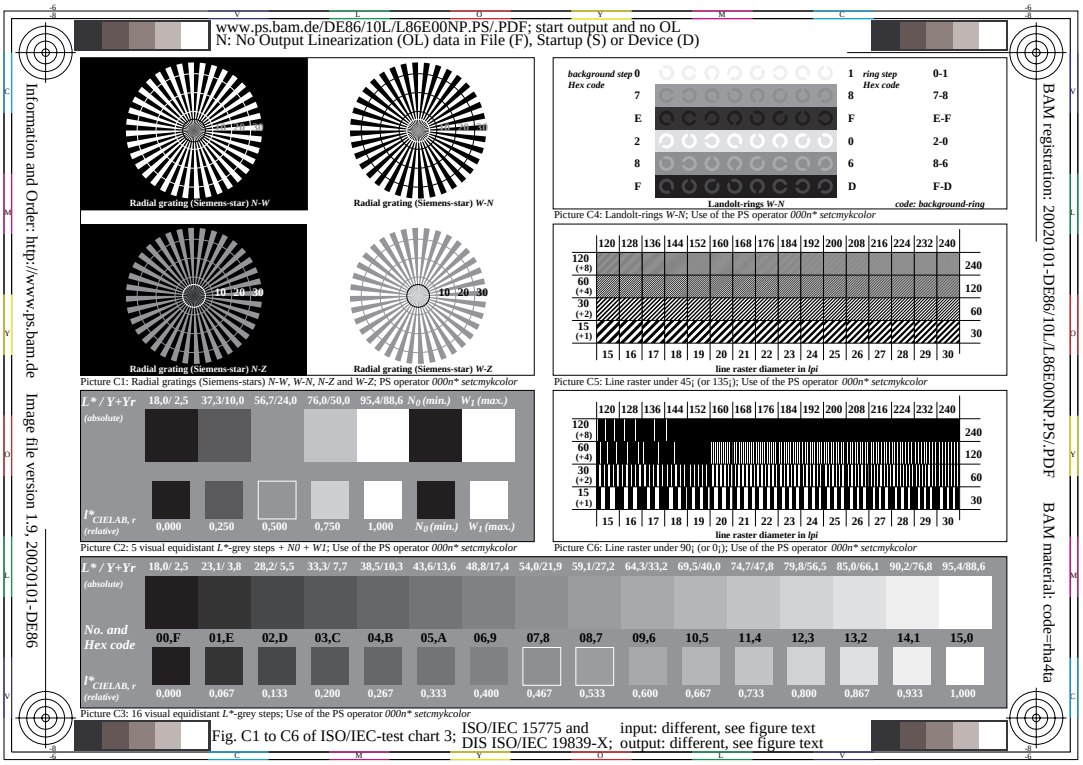

Figure 8: Fig. C1 to C6 of the ISO/IEC-test chart 3; colours are defined by the input PS operator *000n* setcmykcolor* without any transfer; see for the original NP file
http://www.ps.bam.de/DE86/10L/L86E00**NP**.PDF

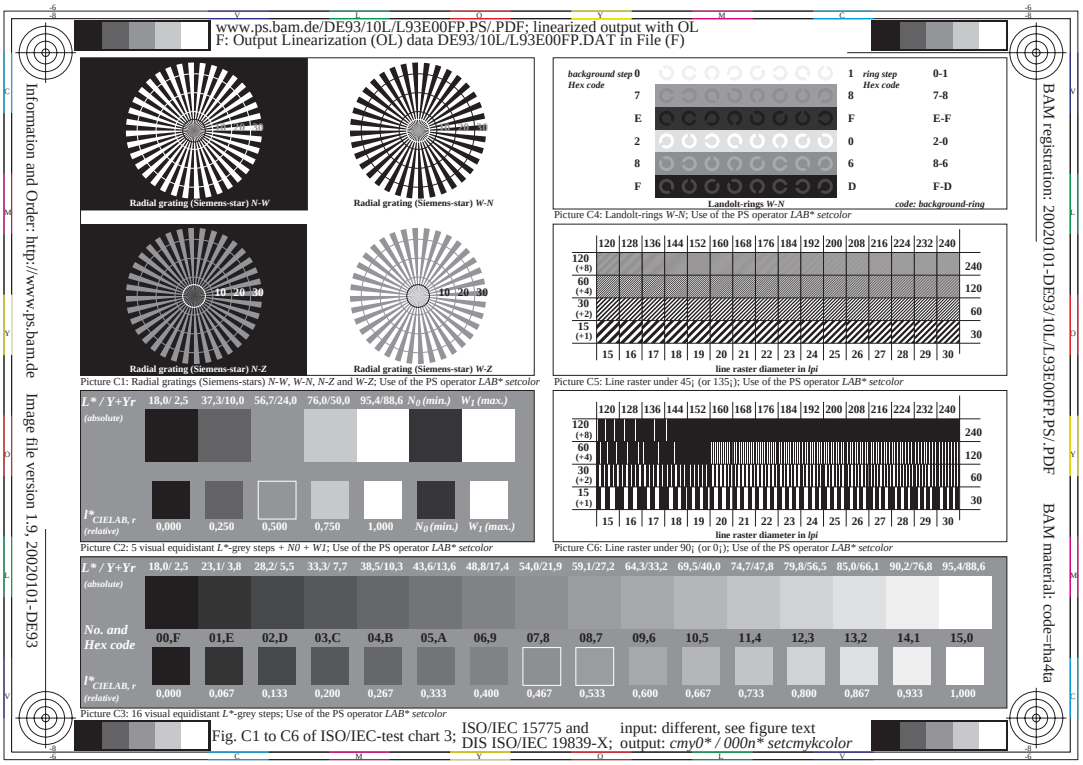

Figure 9: Fig. C1 to C6 of ISO/IEC-test chart 3; colours are defined by the input PS operator *LAB* setcolor* and transferred to the output PS operator *000n* setcmykcolor*; see for the original FP file
http://www.ps.bam.de/DE93/10L/L93E00**FP**.PDF

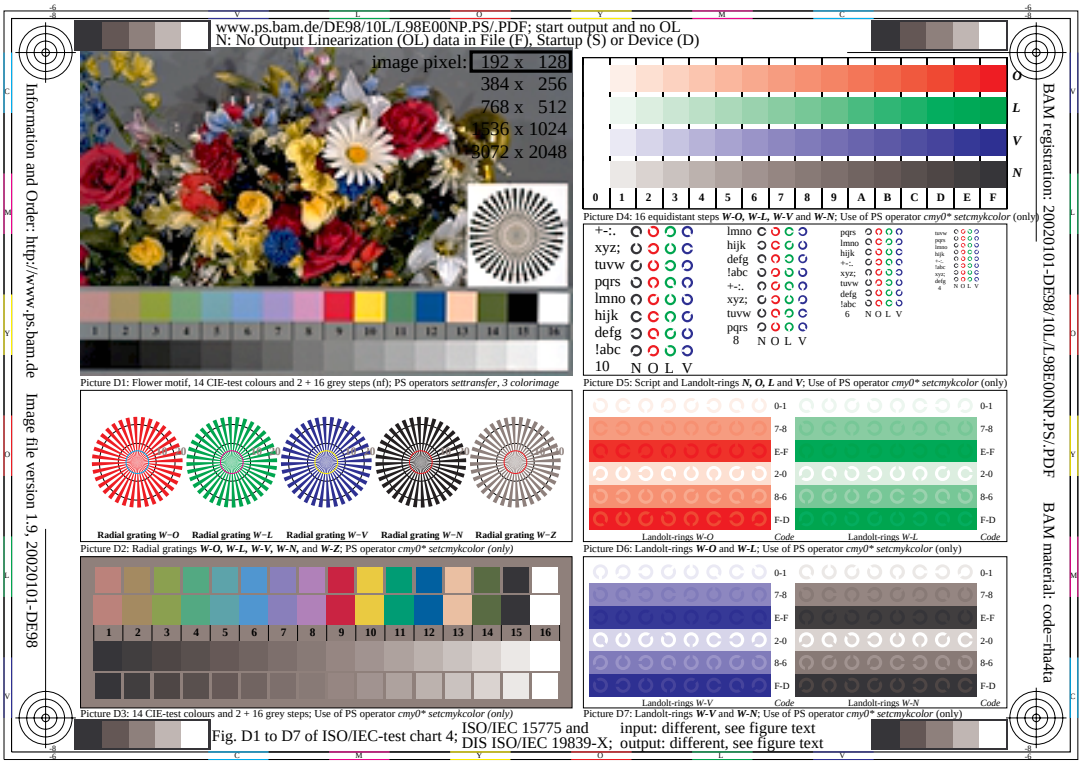

Figure 10: Fig. D1 to D7 of ISO/IEC-test chart 4; colours are defined by one input PS operator *cmy0* setcmykcolor (only)* without any transfer; see for the original NP file
http://www.ps.bam.de/DE98/10L/L98E00**NP**.PDF

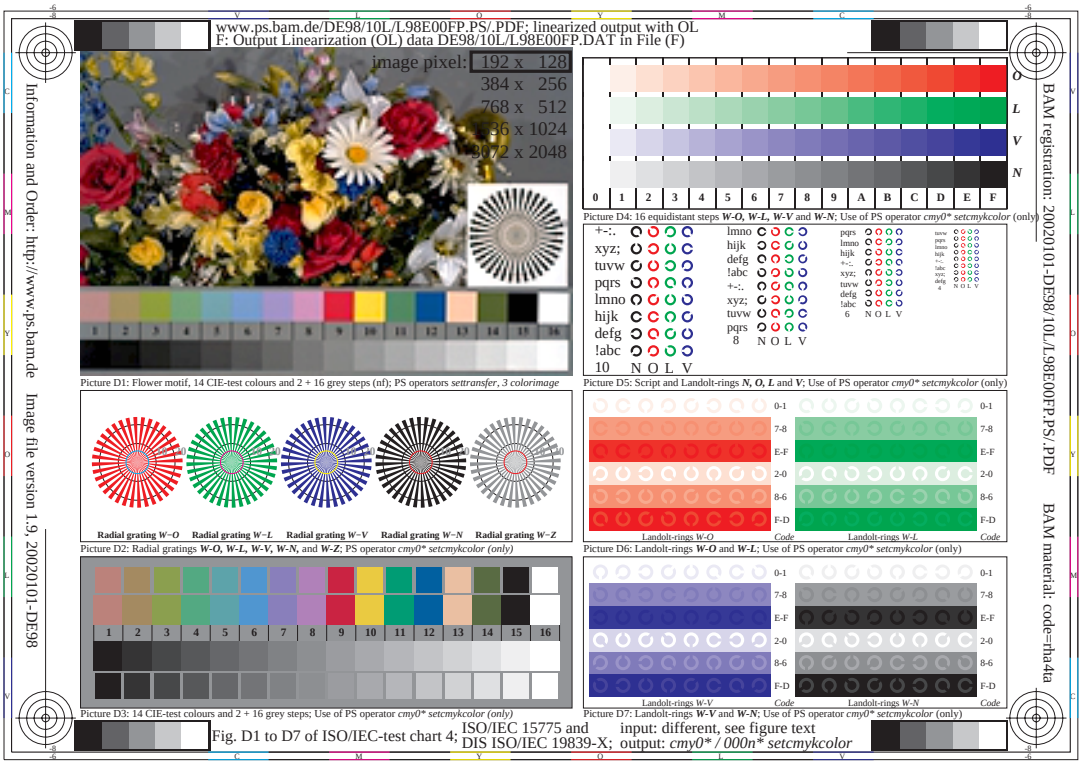

Figure 11: Fig. D1 to D7 of the ISO/IEC-test chart 4; colours are defined by the input PS operator *cmy0* setcmykcolor (only)* which is transferred to the one output PS operator *cmy0* / 000n* setcmykcolor*; see for the original FP file

http://www.ps.bam.de/DE98/10L/L98E00**FP**.PDF

For instance the output of the grey changes by the software *Adobe Reader* from brownish to neutral on the monitor.

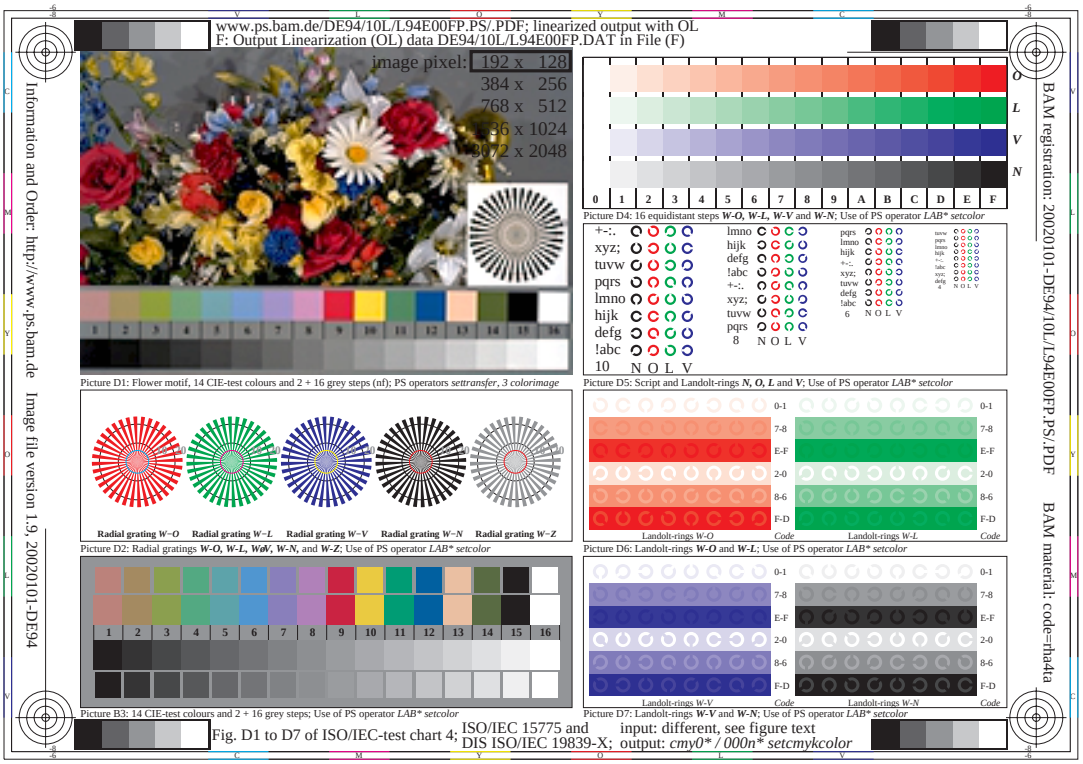

Figure 12: Fig. D1 to D7 of the ISO/IEC-test chart 4; colours are defined by the PS operator *LAB* setcolor* which is transferred to the one output PS operator*cmy0* / 000n* setcmykcolor;* see for the original FP file

http://www.ps.bam.de/DE94/10L/L94E00**FP**.PDF

The ISO/IEC-test charts no. 3 (GREY) and no. 4 (OLV colours) in the NP form are proposed for the tests according to DIS ISO/IEC 19839-X. The ISO/IEC-test chart file 3 in the FP form allow to linearize the output on different printers. Then the letter A, O, T is used instead of L on the web site for three different printers. The *LAB** data of the start output are included in these FP file and the FP files are only useful if the corresponding printer or device is present.

4.0 NP Files for the start output and the measurement of the *LAB** data

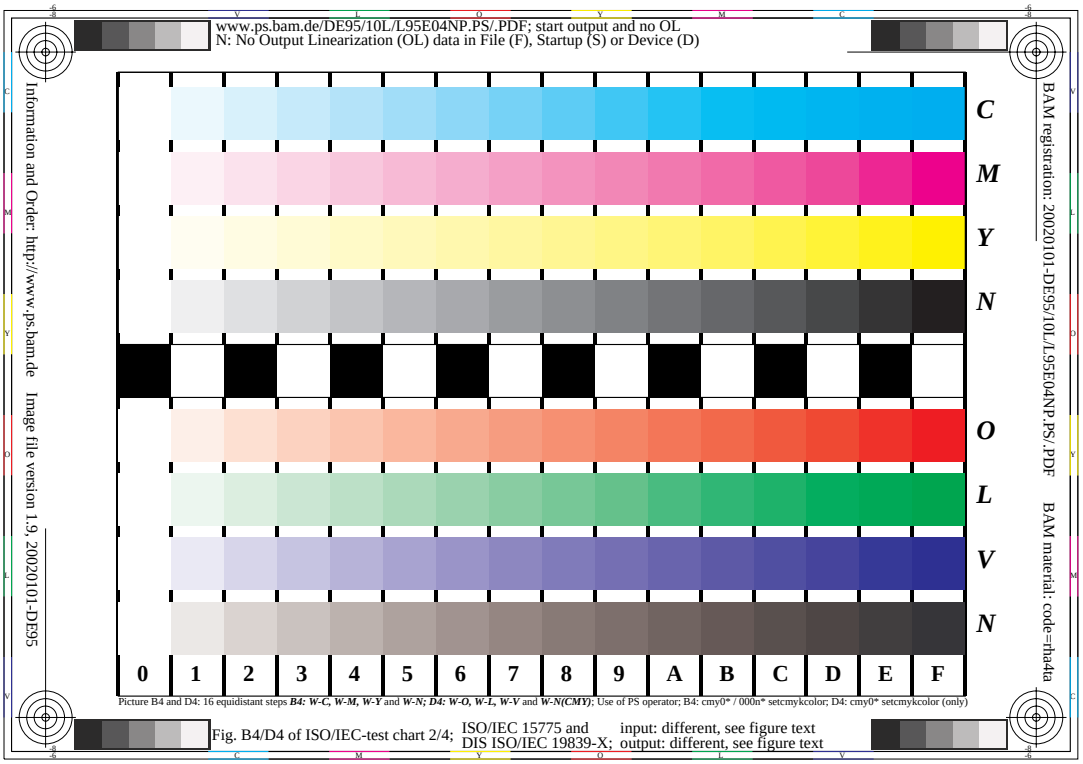

Figure 13: Fig. B4 and D4 of the ISO/IEC-test chart 2 and 4; colours are defined by the input PS operator *cmy0* / 000n* (B4) and cmy0* (only) setcmykcolor (D4)* without any transfer; see for the original NP file http://www.ps.bam.de/DE95/10L/L95E04**NP**.PDF

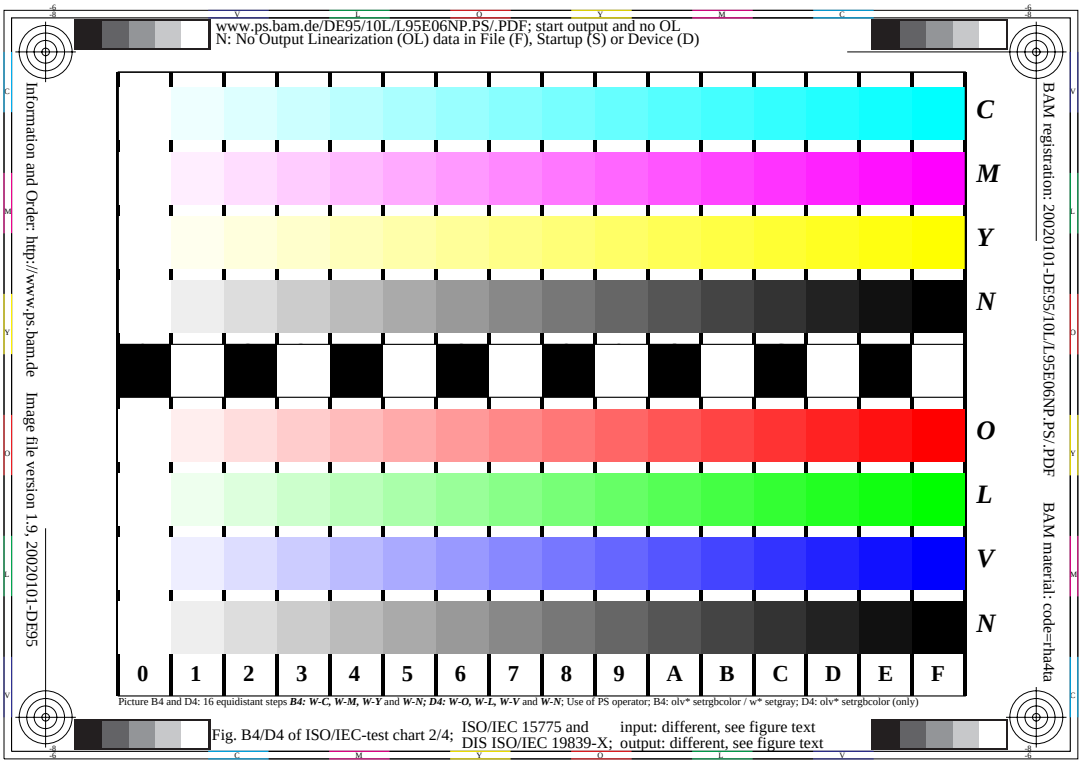

Figure 14: Fig. B4 and D4 of the ISO/IEC-test chart 2 and 4; colours are defined by the input PS operator *olv**

***setrgbcolor / w* setgray (B4)* and *olv* setrgbcolor (only, D4)* without any transfer; see for the original NP file** http://www.ps.bam.de/DE95/10L/L95E06**NP**.PDF

For CIELAB measurement the colour patches of ISO/IEC-test charts (7 mm square) are often too small. The following files produce larger patches (14 mm square) which can be used to measure the *LAB** of the start output. It is required to include the *LAB** data at the appropriate place in the FP files within the MTL code.

If for output the PS operator *cmy0* / 000n* setcmykcolor* is preferred, then it is required to measure the 128 colours of the following file.

Remark: Software which is in agreement with CIE colorimetry produce the same output on printers and monitors for the NP files of Fig. 13 and 14 and then there is no need to measure the output twice

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Conclusion

The standard digital ISO/IEC-test charts (NP files) are useful to test the colour output on the different devices. If different results of the different software products on the different devices appear on output then the user can make the appropriate decision according to his technical requirements.

If DIS ISO/IEC 19839-X is accepted as International Standard then new optional device drivers according to ISO/IEC 18839-X are expected. If the MTL method is used then the present large output differences usually reduce by a factor 3 to 5. If the coordinates in the corresponding colour spaces are used, then equal output on devices is expected. The example solutions with the FP files of the ISO/IEC-test charts help users and manufacturers and will appear in an ISO/IEC technical report (already approved in ISO/IEC JTC1/SC28) with K.Richter as Editor.

Remark: The method with the MTL code is **not** intended to replace colour management methods of professional graphics but it may be used to improve the output, e. g. to adapt the results to output paper and other variations.

References

[1] **DIN 33866-X**: Information technology ‹ Office machines ‹ Machines for colour image reproduction:
DIN 33866-1, Edition:2000-07; Part 1: Method for specifying image reproduction of colour devices by digital and analog test charts, Classification and principles; This standard includes analog DIN-test charts no. 1 to 4
DIN 33866-2, Edition:2000-10; Part 2: Method for specifying image reproduction of colour devices by analog input and analog output for colour image reproduction devices: analog ‹ analog (copiers) - Realisation and application
DIN 33866-3, Edition:2000-07; Part 3: Method for specifying image reproduction of colour devices by digital input and analog output as hardcopy for colour image reproduction devices: digital - analog (printers) - Realisation and application
DIN 33866-4, Edition:2000-10; Part 4: Method for specifying image reproduction of colour devices by analog input and digital output for colour image reproduction devices: analog - digital (scanners) - Realisation and application
DIN 33866-5, Edition:2000-10; Part 5: Method for specifying image reproduction of colour devices by digital input and analog output as softcopy for colour image reproduction devices: digital - analog (monitors) - Realisation and application

[2] **DIS ISO/IEC 19839-X**; Information technology - Office machines - Colour image reproduction equipment, see www.ps.bam.de/IEDIS/IEDIS.HTM
DIS ISO/IEC 19839-1, Edition: 2001-09-Part 1: Method for specifying image reproduction of colour devices by digital and analog test charts, Classification and principles, 41 pages
DIS ISO/IEC 19839-2, Edition: 2001-09; Part 2: Method for specifying image reproduction of colour devices by digital input and analog output as hardcopy for colour image reproduction devices: digital - analog (printers) - Realisation and application, 26 pages
DIS ISO/IEC 19839-3, Edition: 2001-09; Part 3: Method for specifying image reproduction of colour devices by analog input and digital output for colour image reproduction devices: analog -digital (scanners) - Realisation and application, 24 pages
DIS ISO/IEC 19839-4, Edition: 2009-09; Part 4: Method for specifying image reproduction of colour devices by digital input and analog output as softcopy for colour image reproduction devices: digital - analog (monitors) - Realisation and application, 31 pages

[3] **ISO/IEC 15775**, Edition 1999-12; Information technology ‹ Office machines ‹ Machines for colour image reproduction - Method of specifying image reproduction of colour copying machines by analog test charts ‹ Realisation and application